PRELIMINARY NOTE ON THE GEOLOGY OF THE QUEENSLAND COAST WITH REFERENCES TO THE GEOGRAPHY OF THE QUEENSLAND AND N.S. WALES PLATEAU.

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SYNOPSIS OF CONTENTS.

Introduction.

Rock composition, geologic structure, coastal movements, and the agents of denudation are the codependent criteria of any theory as to the origin of present land forms.

Of late years the study of the topographical features of a country as illustrating its geological history has received much attention.

The evolution of mature river systems from plateaux of accumulation and erosion; the appearances of land forms in gently sloping and steeply inclined strata and the influences of subsidence, elevation and marine erosion in the formation of coast lines are clearly brought out by this branch of geological research.

The advantage of grasping the meaning of the more important scenic features of a locality is that a cursory visit to the place will often suffice to make clear the leading points in its history.

For instance, a mere cruise along the coast is sufficient to note "the regular and rhythmical curves"* which mark the effect of *long-continued* marine erosion; the multitude of islands surrounding an irregular coast which speak of recent subsidence; or pyramidal and flat-topped mountains, skirted by coastal plains, which tell the passer-by of plains of accumulation elevated by crustal movements to plateaux of accumulation, the subsequent loss suffered through the agents of deundation; of the subsidence which followed the formation of river systems in the plateaux of accumulation, and the elevation which transformed the marine beds (formed during subsidence) to coastal plains.

The following brief notes on the geology of Queensland are based mostly on observations during a short trip taken by Mr. C. Hedley and myself along the Queensland coast, and are intended merely as a preliminary note to a more extended paper on the Tertiary history of the Cordillera, the evolution of the present river systems, and the various stages of development of the Queensland and New South Wales coasts.

To these notes on Queensland coast topography are added references to N.S. Wales topography based on personal observations along the plateau and coast.

I desire here to express my sincere thanks to Mr. Hedley for much valuable information concerning the Queensland coast, and at whose suggestion the trip was undertaken; to Mr. J. M. Newman, B.E.; Captain Almond, of Brisbane; Mr. Patience, of Townsville; Captain Reader, of Lucinda Pt.; Mr. Brooks, of Tully River; Messrs. Cutten Bros., of Clump Pt.; Mr. George Butler, of Townsville; and many others for information and hospitality.

* Reclus.

Physiography.

1. *General appearance, &c.*—From the Tweed Heads to Thursday Island the coast is of the highly indented type, bordered with broad coastal plains. A wide continental shelf exists from north to south, dotted over with innumerable islands, many of them rugged and mountainous in character.

South of the Great Barrier Reef we have the large islands known as Stradbroke and Moreton, from which to the north and west extend wide coastal plains, especially wide in the neighbourhood of the Glass House Mountains, which consist of trachytic lavas weathered into most fantastic shapes.

Further north Frazer (80 miles in length) and Curtis Islands occur, both separated from the mainland by long, narrow, and shallow channels, also accompanied by great sandy flats and small islands. Lady Elliot Island and The Bunkers form the southern outposts of the Great Barrier Reef, and occur a little north of Frazer Island.

From Mackay to Cairns the coast is very rugged. Great mountains advance into the sea; numerous bold promontories and islands such as Cape Cleveland, Cape Upstart, Castle Hill, Cape Grafton, Lion Island, Gloucester, Hinchinbrook, Whitsunday and Palm Islands are separated from the mainland by long and narrow channels or broad flats a few feet only above high-water mark.

The flats which gather at the bases of these headlands and coastal ranges are very conspicuous.

In many cases these headlands consist of barren rocks, showing a great wealth of enormous precipices and escarpments covered with rounded boulders, illustrating the granitic type of weathering.

2. *Coastal plains.*—These are very extensive along the Queensland coast, and represent the redistribution by tidal action of fluviatile material, and to a less extent that derived from the headlands by marine erosion.

Around Brisbane and the Glass House Mountains these flats are as much as 20 miles in width. To the west the mountains rise precipitously from them. As seen during a journey up the Brisbane River they, together with St. Helena, Mud and Peel Islands, appear due to a slight elevation. The Glass House Mountains stand out like islands in the centre of this plain. In this connection Mr. J. M. Newman, B.E., writes:—"I think they are undoubtedly the result of recent elevation. For fully 10-20 miles inland the country is more or less flat and sandy. For a few miles in from the coast one finds even now bits of recent shells; also there are large swamps and lagoons, the remnants apparently of rivers whose mouths have been silted up by bars. The water runs in them now only in flood time. What ridges there are are low and sandy, and the swamps and paddymelon-hole gullies run between them. As you go inland the ridges become higher and less sandy, forming gradually the spurs of a low range of mountains at the back of the Glass House Mountains. These latter rise sheer out of the coastal flats, and seem to have been submarine in origin. . . . In the coastal regions one finds a few feet beneath the sand a sort of pipeclay, with ironstone nodules extending to a great depth."

Dense mangrove swamps have fastened on to the seaward edges of these plains.

Another great "coastal plain" exists off the mouth of the Burnett, and others around Maryborough.

Well marked also is the recent gain to the coast by these flats in the neighbourhood of Rockhampton, and due to the action of the Fitzroy River.

At Keppel Bay great dismal mangrove swamps extend for miles. These pass into the flats just mentioned.

Again at Mackay similar broad flats exist.

When nearing Townsville the enormous headlands and attendant flats are marked features in the scenery. In almost every case the mountains of the coast line rise sheer out of the low ground until far out at sea they appear as islands.

Especially emphasised is this association of steep mountain and lowly flats in the neighbourhood of Hinchinbrook Island and the Herbert River (Fig. 1).

Fig. 1.—Sketch Section from Mainland and Hinchinbrook Island to Outer Barrier.

1. Granite of Mainland and Continental Shelf. 2. Round Mt. 3. Hichinbrook Island (Mt. Bowen). 4. Coastal Plains. 5. Hinchinbrook Channel. 6. Siliceous Material deposited on Shelf from Rivers, &c. 7. Britomart Reef. 8. Outer Barrier. 9. Coral, Shells and Coralline material. 10. Late Tertiary Beds on which Great Barrier Reef has grown. *aaaa*. Probable Contour of Bed Rock (Shelf) of Granite or Permo-Carboniferous Strata.

Vertical Scale much exaggerated, being 20 times Horizontal Scale (Horizontal 1 in. = 8 miles. Vertical $1\frac{1}{2}$ in. = 2000 ft.)

Here great mangrove swamps, miles in width, pass into flats as much as 20 miles across in places, and from which the great coast range rises. From these extensive flats monadnock-like* forms arise, for example, Glass House Mountains. North of Cardwell the great extent of coastal plain around Rockingham Bay, traversed by the Tully, Murray and Hull Rivers, forms a conspicuous object in the topography.

At Cairns other great coastal flats exist. One interesting plain between Cape Grafton and False Cape may be noted here. It is about a mile across and two miles long; and but a few feet above high tides.

We have thus found these large flats or "coastal plains" raised but a few feet above high tides to exist right along the eastern coast of Queensland.

They appear almost undoubtedly to be matter derived from the large coastal rivers and from the forces of marine erosion redistributed by the various agents of along shore action.

"They are due to fluviatile action being invariably absent from coasts possessing no considerable rivers."†

A slight elevation would account for their present position.

Similar flats will be described under the head of islands.

Associated with these plains are numerous lagoons, lagoon marsh meadows, and shallow creeks. Especially well are these seen along the coast between Rockhampton and the Tweed Heads.

3. *The Continental Shelf.*—This, in Queensland, maintains generally a great width. To the south of the Great Barrier Reef it is represented by reefs of old stratified rocks, enormous shoals, and soft deposits uniformly distributed over the surface, and having a gradual dip to the east, and which rise 40 or 50 miles away to the east from enormous depths.

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* An isolated hummock or hill rising from a surface developed by subaerial agencies to extreme old age.

† Prof. Pencke, Morphologie der Erdoberfläche.

On the northern submarine extension of Breaksea Spit, which is composed almost entirely of "siliceous material,"* are situated Lady Elliot Island and the Bunker Groups.

Northwards again the outer edge of the shelf is represented by the Great Barrier Reef itself, occurring at distances varying from 15 to 100 miles from the coast. Long lanes of coral sand and wide openings break into the integrity of the ocean front of the Reef.

Deep gutters of valley form occur in a few instances on the continental shelf, and in the vicinity of the outer barrier.†

A few miles from the shore line great numbers of precipitous islands exist, rising from shallow water, rarely if ever exceeding ten fathoms in depth. These islands are often accompanied by small fringing reefs, and in many cases also by plains, miniatures of the large occurrences on the mainland, and described under "Coastal Plains." In many cases the axes of the mountain ridges composing the islands are parallel to the main coast line, and are separated therefrom by narrow channels (*e.g.*, Hinchinbrook, Molle, and Albany Passages).

4. *Islands*.—Stradbroke, Moreton and Frazer Islands are huge sand piles lying to the south of the Great Barrier Reef. They are respectively 35, 20 and 80 miles in length, and appear due to the redistribution of fluviatile and other material by marine and æolian agencies. In the cases of Stradbroke and Moreton Islands the northern extremities consist of older stratified rocks, and these uncovered masses of continental rocks doubtless belong to a series of small insular patches on which the threefold action of rivers, wind and currents have worked, first to tie the islands together, and afterwards to fashion the large sandy masses into their present appearance. As a result of long-continued residence and observation on those islands, Mr. Hedley is of opinion that

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* Jukes, Voyage of "Fly," Vol. i., p. 318. See also A. Agassiz, "Great Barrier Reef of Australia," pp. 64, 105.

† *Ibid.*, Vol. i., p. 345.

the only continental rocks now visible are those to be found at the northern island extremities.

Frazer Island likewise appears to be composed of sand. In all cases these islands are associated with large rivers and coastal plains. They have straight eastern coast lines 50 or 60 miles long, while straight or swinging sandy coasts with enormous coast plains, lagoons, creeks, monadnocks, lagoon-marsh meadows, and with gently sloping off-shore deposits constitute the chief features of the neighbouring mainland.

Near the mouth of the Fitzroy River numerous insular patches occur, the longest of which is Curtis Island, running parallel to the mainland, and separated from it by a long narrow channel, in which the variation in the tides amounts to as much as 27 feet. This island is composed in great part of sand; it contains signs of elevated beaches,* and is associated with extensive coastal plains.

The Beverley and Northumberland Groups comprise numerous small rocky and pine-clothed islands, usually presenting mural fronts to the sea—the result of marine erosion.

In the Whitsunday Group are islands of considerable size, separated from each other and the main coast by narrow channels of great length.

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* As no notice of this has appeared in literature, Hedley supplies the following note :—

" A striking instance of apparent elevation was shown to me by Mr. J. B. Paterson, the lessee of Curtis Island, Q. A few miles south-west of the Cape Capricorn Lighthouse occur what are locally called the Marine Plains. These are an extensive series of swampy flats, some miles inland, occupying bays in the hilly country and margined by a continuous beach-bank, composed of sand and recent sea shells. Within the bays are small rocky ' islands ' with wave-eroded flanks, and also encircled with beach-banks.

" When I saw it fifteen years ago this scene impressed me as indicating a recent and slight upheaval. But further study of beach-formation convinces me that elevation is not the only possible explanation of the phenomena described. Should the entrance of a shallow bay become blocked by beach-banks or dunes, the consequent shutting out of the sea might leave the head of the bay in such a condition as the Marine Plains of Curtis Island, without the intervention of elevation."

Gloucester Island rises abruptly from the sea to a height of 2,000 feet, and from a short distance much resembles a giant headland, so narrow is the channel between it and the Queensland shore.

Magnetic Island, 1,600 feet in height, is roughly rectangular in plan, and composed of a dark granite admirably adapted for building purposes. Unlike the granite of the Townsville foreshores (five miles distant) and Castle Hill, it is homogeneous in character, and possesses cuboidal jointing. This island is further interesting by reason of certain rock-markings which point to recent elevation. Mr. G. Butler, of Townsville, mentions the presence of masses of oyster shells at a height of from 10 to 15 feet above H W.M., and removed some 50 feet from the sea. These shells, he says, are attached to the solid granite composing the island, and not to loose boulders. Maitland, also, from a discovery of pumice fragments some distance from the present sea level, claims recent elevation for this island.*

The Palm Islands.—This cluster was examined in some slight detail, and was found to consist of granites of varying acidity and quartz-porphyry, traversed by regular networks of basalt dykes.

Generally speaking, they are rugged and barren in character, and, with the exception of a few sandy bays, possess precipitous and rocky coasts. Large black rounded granite tors cover the hill sides.

South Palm is 7 miles in length and about 3 in width. It consists of two peaks 1,400 and 1,820 feet respectively in height. The rock of the island is an ordinary ternary granite, with a tendency, however, to pass into acid types by reason of a diminution in the quantity of biotite. Large segregations of quartz and pink orthoclase may be seen in the granite outcrops. Masses of orthoclase occur as much as 12 to 15 inches in diameter, as also quartz. On the north-east of the island a remarkable floor or

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* Maitland, Rept. Magnetic Island. Brisbane, by authority, 1892.

table of aplite occurs, traversing the ternary granite of the locality. It has the appearance of a fine-grained white sandstone. Its dip is about 10°, and it may be traced over an area of at least five acres.

At Challenger Bay an interesting flat occurs joining two high points of the island, which, but for its presence, would exist as separate islands.

The flat is about one and a half miles in length and 500 yards in width, with an average height above H.W.M. of at least 15 feet.

A gutter some six feet wide and ten feet deep has been excavated through the centre of this flat by the forces of erosion. The structure of the plain as revealed by this miniature valley is a sandy clay, coarse sand, and a clay containing angular fragments of granite. No shells or calcareous material were seen, although careful search was made.

Fig. 2.—Sketch Section across Palm Island "Raised Plain."

a. Mt. Bentley, 1800 feet high. *bb.* Granite of Palm Island. *cc.* Raised Plain, 1½ miles long, 600 yards wide, and from 10 to 15 feet above H.W.M. *dd.* Probable Contour of underlying Granite.

On the southern side of this flat large quantities of pumice occur, high above high water mark, and stretching inland for some ten chains. The flat is covered at present with growths of eucalypts, pandanus, and coarse grass about four feet in height.

A similar though smaller occurrence was observed by Mr. Hedley near Bentley's Creek.

These flats, in my opinion, point undoubtedly to the redistribution by tidal action of matter lost to the mainland and adjacent islands, but principally by loss to the South Palm itself by the forces of marine erosion acting on the windward side.

Fig. 2A.—Section from Mainland to Palm Islands.

1. Basal Granite. 2. Coastal Plains. 3. Recent Deposits, 4. Mt. Bentley, Palm Islands (1800 ft,).

Horizontal Scale, 1 inch = about 4 miles. Vertical Scale, 1 inch = 4,000 feet.

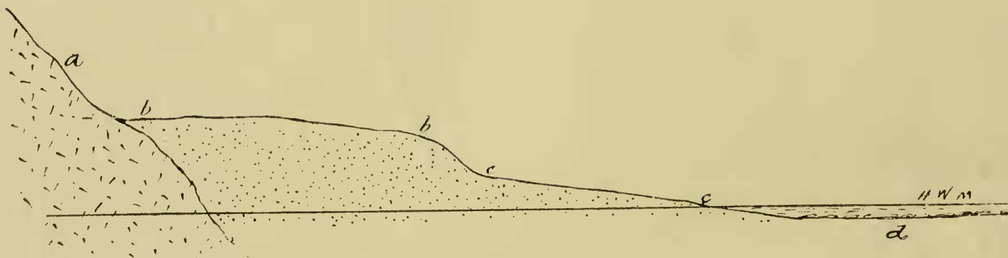

Fig. 4.—Section across Windward Side of Fantome Island (Lat. 19° S).

a. Granite. *bb.* Beach, 12-15 feet above H.W.M., consisting of blackened coral and shell fragments and many large pieces of "beach-rock," apparently *in situ*. *cc.* Present beach. *d.* Fringing Reef.

Horizontal Scale, $\frac{3}{4}$ inch = 1 chain. Vertical Scale, 1 inch = 20 feet.

Signs of elevation were also present on this island in the shape of beach rock apparently *in situ*, and some eight feet above high tides.

The reefs around the S. Palm Island are of the small fringing type, and in common with those existing on the other islands on the Queensland continental platform lack the luxuriance and beauty of those seen on the outer edge of the Great Barrier Reef or those in Fiji waters (Fig. 3*a*).

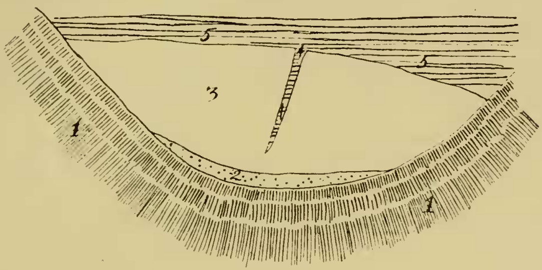

Fig. 3*a*.—Sketch Plan of Fringing Reef at South Palm Island.

1. Coast Mountains. 2. Beach. 3. Fringing Reef. 4. Gutter in Coral Reef (5 chains long). 5. Sea (10 fathoms deep).

A curious and instructive feature was observed in the fringing reef to windward. Here the reef is about 10 or 12 chains in width, and rises from 10 fathoms water. A long lane of water, a chain in width, is cut clean as with a knife across the reef,

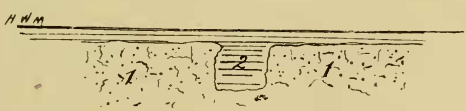

Fig. 3*b*.—Sketch Section across Gutter in S. Palm Island Fringing Reef.

1. Coral Reef. 2. Gutter (60 feet deep, 1 chain wide),

reaching almost to the shore. No corals whatever were observed growing in this lane; the sides are precipitous, and 10 feet below the surface appear to be slightly overhanging in character (Fig. 3*b*).

Orpheus Island, also composed of granite and quartz porphyry, crossed with basalt dykes, contains on its sheltered side an extensive flat some 12 feet above H.W.M., and composed of black coral fragments; some as much as three feet in diameter.

Fantome Island, also of granite and quartz porphyry, possesses two flats—one on the windward, the other on the leeward of the island. The more important one lies between two neighbouring granite hills. The seaward edge consists of a long sloping white beach, skirting a fringing reef, which is exposed in great measure during low tides. Beyond the present line of beach another rises in similar form to a height of 12 to 15 feet above spring tides, forming a wide and distinct terrace as much as five chains wide in places.

Large fragments of "beach rock" exist on this upper beach apparently *in situ*, the pieces having a gentle slope seawards. A forest growth has seized upon this higher beach, and almost concealed it from view.

A similar though smaller flat occurs on the leeward side. In the cases of Orpheus and Fantome beaches the arms of the sea in a couple of instances are less than half-a-mile in width in the locality, and in these waves could not have such play as on exposed ocean beaches.

Curious umbrella-like coral growths occur in Juno Bay, Fantome Island. The accompanying diagram is a sketch section of two of these growths near one of our anchorages (Fig. 5).

These interesting growths rise from as much as 30 and 40 feet depth of water, and form shelters for fish. It is very probable that in time to come some of the upper portions may coalesce by fusion of the growing walls, leaving a species of cavern below.*

Curaçoa Island is small and conical in shape, composed of granite and porphyry. It is 920 feet in height. On its western side a flat of some 50 acres exists. Mr. G. Butler, of Townsville, states that this flat is composed almost entirely of large black coral fragments, at least 12 feet above high water mark.

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* Sawyer and Andrews, "Caves of Fiji." Proc. Linn. Soc. N.S.W. 1901 xxvi., Pt. 1, pp. 91-106.

Hinchinbrook Island consists of huge rock escarpments, surmounted by aiguilles—a mountain range 20 miles in length, whose

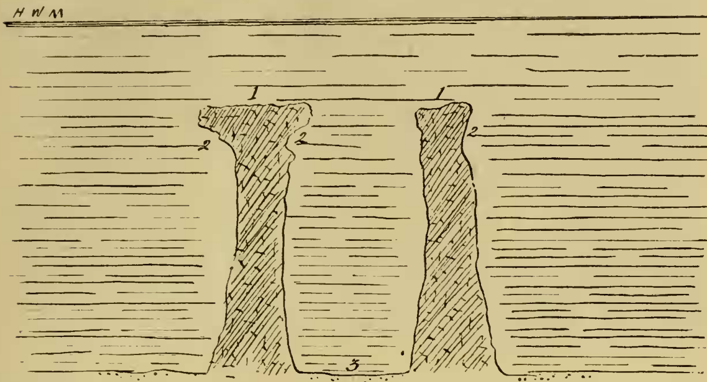

Fig. 5.—Sketch Section illustrating interesting Coral Growths at Juno Bay, Fantome Island.

1. Flat growing coral tables, from 6 to 10 feet in diameter, 10 feet below H.W.M. 2. Rockshelters under coral tables. 3. Sand lanes.

Height of pillars about 30 feet.

axis is approximately parallel to the neighbouring mainland coast. Immense mangrove flats, miles in width, fringe its western edge, and from these rise precipitously the great granite peaks known as Straloch, Diamantina, Pitt and Bowen, the latter being nearly 4,000 feet in height. The southern portion contains many barren peaks, and exhibits the granite type of weathering. The northern end of the island is devoid of the rugged peaks of the south, and is composed principally of a dark quartz porphyry.

A long narrow channel (in places nine fathoms deep) separates the island and the mainland. If, as seems undoubtedly the case to me, the Hinchinbrook flats argue recent elevation, then this channel must previously have been much wider, yet of the nature of a shoal at low tides over which no heavy waves could beat, the present channel having been determined by subaerial denudation ante-dating the period of subsidence. Consequent drainage is a striking feature of these elevated flats, and islands connected by sand ridges are common on the north-eastern side.

Goold Island is 1,400 feet in height, and composed of granite of acid type. Here, as at the Palms and Hinchinbrook, quartz porphyry is a common rock-type, weathering generally into rectangular blocks, at times simulating the structures observable in stratified rocks, thus differing from the ordinary spheroidal and dome-shaped masses characteristic of granitic weathering.

Dunk Island is of small extent, and covered with a dense jungle or "brush." It consists of Silurian slates, quartzites, tuffs and schists, and lies some five miles distant from the mainland, which at this point also is composed of similar rocks, and supports exceedingly dense forest and jungle growths (Fig. 6).

Fig. 6.—SECTION ACROSS DUNK ISLAND.

a. Present reef. *bb*. Coastal plain 20 feet above sea-level. *c*. Cañon, 20 feet deep, exposing section of coastal plain. *d*. Contorted rocks (slates, schists and quartz rocks).

Horizontal Scale, 1 inch = 250 yards.

The island proper consists of high rough land meridionally disposed. On the side facing the mainland (leeward) a most interesting flat occurs. It is between one and two miles in length, and 500 or 600 yards in width. A low bench, two or three feet above high water mark and several chains in width, accompanies it for a considerable distance on its seaward edge, and to this the flat presents a mural front 20 feet in height. Its structure, as revealed by an examination of the seaward edge, and that exposed in a 20 feet section made by a small cañon cutting across its breadth is that of a stiff clay, or clay and sand admixtures, containing numerous angular and subangular fragments of the local rocks. Shells and other calcareous matter are conspicuous by their absence. At present its surface is covered with thick growths of eucalypts, jungle, pandanus and grass. This flat is doubtless due to redistribution by along shore action of matter lost to the island by marine erosion.

South Barnard is a very small island composed of basic tuffs, strengthened by several great vertical basaltic dykes, whose powers of resistance have prevented the little island from being reduced to a terrace of erosion.

A small sandy flat exists on one side of the island, and at a height of 20 feet above high water mark, on the southern side, indistinct traces of a line of former beach erosion were seen, which reminded the writer somewhat of the elevated lines of marine erosion seen in many of the Fiji Islands.*

The *North Barnards* are small, tuffaceous in character, densely brushed, and present mural fronts at times to the sea.

Fitzroy Island, nearly 1,000 feet in height, is rugged in character, and, in common with the other islands of granitic composition on this coast, is surrounded, as to its shore line, with great spheroidal blocks.

A small beach exists on the north-west side of this island, exceedingly interesting by reason of :—

(*a*) Its steep slopes.

(*b*) Its terraced appearance.

(*c*) The occurrence, in the bed of a small creek cutting across it, of dense hard "beach rock."

A section determined by Mr. Hedley and myself is supplied illustrating its excessive steepness (27°), and the great height (18 feet) of the second terrace above high tide mark.

The lower beach consists of white coral and shell fragments, while the upper one is composed of similar material, but quite black in colour. The section was taken near the south-western extremity of the beach.

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* Andrews, "Notes on Geology of Fiji." Bull. Mus. Comp. Zool. Harv. Coll., 1900, xxxviii.

Fig. 7.—Section of Beach on S. West end of Fitzroy Island.

a. Present Reef. *bb*. Present Beach. *cc*. Higher terrace (beach) composed of blackened fragments of coral, 2 chains in width. *dd*. Probable position of basal granite.

Vertical Scale, 1 inch = 18 feet.

King* ascribes the origin of the higher beach to gale action, and Prof. Agassiz refers it also to similar agencies.† G. Elphinstone Dalyrmple also refers it to elevation.‡ In this connection Brazier§ writes :—"The beach (at the Fitzroy landing place) was composed of nothing but coral and shells, about 30 yards long, six to seven feet in thickness, and the same in breadth. During my second visit (1875) the whole of the bank had been washed away by some heavy gale." As, however, the present beach is 500 or 600 yards long and several chains in breadth the excision of such an insignificant fragment as mentioned by Brazier would not affect the general appearance of the beach.

The occurrence of "beach rock" in the bed of a stream of fresh water, compact and hard almost as building limestone, is very interesting, pointing to its origin (as suggested by many geologists) being referable to the action of fresh water.

From the summit of Fitzroy the sunken coral patches of the outer Barrier could be seen for miles.

Green Island is small, and consists of sand scattered over a base of coral. It is merely a portion of the Great Barrier Reef itself, determined partly by elevatory forces, and partly by the combined efforts of æolian and marine agencies, and populated by animal and vegetable waifs from the neighbouring mainland, which at this point is but a few miles distant.

On the reef surrounding this island coral and other growths are more luxuriant than in the turbid waters around the small islands dotting the continental shelf.

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* Narrative of a Survey of the Intertropical and Western Coasts of Australia, i., 1827, p. 206.

† "A Visit to the Great Barrier Reef of Australia, &c." Bull. Mus. Comp. Zool. Harv. Coll. xxviii., 1898, p. 110.

‡ Brisbane. By authority, 1874.

§ Journal of Conchology, ii., pt. 6, June, 1879.

The Elevation of Eastern Australia compared with that of Melanesia and Polynesia.

In recent times a slight elevation appears to have obtained over the whole eastern coast of Australia, traces of the elevatory movement being recorded at Raine's Islet,* Cooktown,† the islands between Thursday Island and Cairns,‡ Cape Grafton, Dunk Island, Hinchinbrook, the Palm Islands, Magnetic Island,§ Curtis Island,|| Moreton Bay,¶ the various "coastal plains" of Queensland, Ballina beaches,** Hunter River,†† Port Stephens, Hawkesbury River, Botany Bay, Wollongong‡‡ and other places.

This elevation is, as before remarked, so recent that corals, "beach rock," and plains around small islands have suffered scarcely any disintegration.

A similarly slight and recent movement of elevation occurred throughout such island groups as the Fijis, Tonga, and the Solomons so recently that raised "lines of marine erosion" left on the cliffs in places exist almost in their original integrity, though sometimes 30 feet above H.W.M. So also in certain islands in Fiji§§ and the Solomons,|||| raised beaches and coral

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* Dr. Alex. Rattray, "Notes on the Geology of Cape York Peninsula," Quart. Journ. Geol. Soc. xxv., 1869.

† J. E. T. Woods, Proc. Linn. Soc. N.S. Wales, v., 1880, pp. 187-189.

‡ Jukes, Voyage of H.M.S. "Fly," Vol. i.; A. Agassiz, Bull. Mus. Comp. Zool. Harv. Coll. xxviii.

§ Maitland, "Report on Magnetic Island." Brisbane, 1892; G. Butler, Esq., Townsville.

|| *Fide* C. Hedley,

¶ Stutchbury, Twelfth, Thirteenth, and Sixteenth Tri-monthly Reports, N.S. Wales Leg. Council Papers, 1854; R. L. Jack, Geology of Queensland, p. 617.

** J. E. Carne, Ann. Report Dept. Mines N.S. Wales, 1896, p. 151.

†† Prof. David and R. Etheridge, Junr., Rec. Geol. Survey N.S. Wales, ii., 1890.

‡‡ Jukes, Voyage of H.M.S. "Fly," Vol. i., p. 336.

§§ Andrews, "Notes on the Limestones and General Geology of the Fiji Islands," &c., Bull. Mus. Comp. Zool. Harv. Coll. xxxviii., 1900.

|||| Guppy, The Solomon Islands: their Geology, &c.

platforms exist with numerous loose and blackened corals scattered over them.

In these islands, however, this recent uplift represents the final stage in a series of repeated slight elevatory movements, alternating with periods of stable equilibrium, evidenced by "terraces" of coral growths and successive lines of marine erosion. Australia appears to have participated in the most recent one only. Had elevation proceeded in Eastern Australia along similar lines to those pursued in the mid-Pacific, we should have elevated *coral* islands along the site of the Great Barrier Reef in much the same relation to the Queensland coast as the Loyalties (raised coral) are to New Caledonia, the Lau Group to main Fiji (Viti and Vanua Levu), or the smaller coralline islands immediately east of the largest Solomon and New Hebridean Islands to these same land masses.

In certain groups, as in Fiji, coral reefs and atolls were formed during these movements of elevation, which followed a period of great subsidence in Tertiary times, and during which period immense beds of limestone, volcanic conglomerates and Fiji "soapstones" had been laid down to constitute, during the succeeding elevations, a base for the later (recent) "raised reefs." In the New Hebrides, the Solomons,* Fiji,† Tonga,‡ New Guinea§ and elsewhere traces of elevated coral reefs are found from high water mark to a height of 2,000 feet above the same datum line.

The participation by Australia (as regards the Queensland and New South Wales coasts) in the most recent only of these uplifts is very interesting. Hedley|| has conclusively shown from biolo-

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* Guppy, The Solomon Islands: their Geology, &c., pp. 102, 113.

† Agassiz, Bull. Mus. Comp. Zool. Harv. Coll. xxviii., pp. 132-133; Andrews, *ibid.*, xxxviii., p. 27.

‡ Lister, "Notes on the Geology of the Tonga Islands," Quart. Journ Geol. Soc., Vol. 47, 1891, pp. 590-616.

§ Maitland, Geological Observations in New Guinea, 1891, p. 10.

|| C. Hedley, "A Zoogeographic Scheme for the Mid Pacific," Proc. Linn. Soc. N.S. Wales, 1899, pp. 391-417. See also references in same paper.

gical data that the main islands of Fiji, New Caledonia, the New Hebrides and the Solomons were previously coextensive, and these, in turn with New Guinea, continental in origin. Since then geologists* have proved a continental origin for Fiji. Similarly for the New Hebrides, New Caledonia, and the Solomon Islands. If, then, the deep ocean separating these groups represents faulted or warped areas, it is very probable that some relation exists between the subsidences in the ocean area between the island clusters and the repeated uplifts in the groups themselves. The elevation of main Fiji probably proceeded along much more rapid lines than those pursued in the Lau Group, inasmuch as the Tertiary "soapstones," limestones and volcanic conglomerates of Viti Levu appear to have no capping of recent "raised reef," whereas each pause in the elevation of Lau was attended by the formation of "raised reefs" of recent age, having as a base Tertiary rocks indistinguishable from the Viti Levu strata of similar age. (It must be remembered, however, that a very recent uplift seems to have affected main Fiji, Lau, the Solomons and North Australia;† and that, too, after a period of quiescence, as is shown by the raised "coral reef platforms.") The elevations of main Fiji and Lau probably were not synchronous, the main islands of continental origin being rapidly elevated to a great height in one movement, while it is more than possible that the intermittent elevations of Lau were due in great measure to the existence of the large island masses (Viti and Vanua Levu) lying to the West. New Caledonia and the Loyalties form a similar group to Fiji and Lau, so also possibly do New Guinea and the small "terraced" coral islands lying to the east.‡ Thus, whereas the island groups of the Fijis, Solomons, Hebrides, Tonga and New Caledonia have undergone a cycle of elevation, Eastern Australia, as will be shown later, is in a cycle of development attendant on subsidence.

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*W. G. Woolnough, B.Sc., Adelaide University, and Dr. H. B. Guppy, *in litt.*

† This elevation most probably occurred well into the historic period, although the individual island uplifts may not have been contemporaneous.

‡ Maitland, Geological Observations in New Guinea, 1891, pp. 9, 10.

Petrological Notes.

The igneous rocks consist mostly of granites of acid types, quartz and quartz-felspar porphyries, both Palæozoic in age, and intruded alike by regular networks of basaltic dykes.

Granites.—These have a marvellous development, and are principally of acid types. Many of the islands, as also the high coastal ranges, are composed entirely of these plutonic rocks. They are probably Carboniferous and Permo-Carboniferous in age. Quartz and felspar are the chief constituents, although hornblende and biotite are frequently present. In some of the island groups, such as the Palms, the rocks may consist of quartz and felspar, with idiomorphic hornblende and biotite flakes. The hornblende, which is strongly pleochroic, occurs in hexagonal, rhombic and rectangular forms in thin sections, and post-dates the formation of the biotite. Again, hornblende may be absent, while in other cases flat veins of aplite with ill-defined boundaries occur; they are composed mainly of micrographic growths of quartz and felspar. Large segregations of orthoclase and quartz may be seen in the rock exposures, and epidote at times replaces the ferromagnesian constituents. Zircons are associated with the hornblendic varieties. Here, also, crushing is a marked feature. Under the microscope the quartzes and felspars are seen to have undergone great peripheral crushing, besides wholesale fracturing of the different minerals constituting the rock. The grains of quartz and felspar appear as if cemented in a base of the same material (mortar structure). Splendid examples of undulose extinction are shown by both quartz and felspar crystals; long lines of liquid inclusions occur in the quartz, while the felspars (orthoclase and acid plagioclase) show zonary structure, and the development of fresh minerals along solution planes. Biotite also occurs in bent flakes, and secondary quartz is present in great abundance.

Other granites, collected from Fitzroy and Goold Islands although altered, do not show the effects of metamorphism in so marked a degree as the Palm Islands varieties.

Porphyries.—These consist of quartz and felspar idiomorphs scattered plentifully through a fine granular base of the same minerals. The quartz and felspar may be porphyritic towards the rest of the rock. Mica plates are common.

Felspar occurs as stout orthoclase and plagioclase crystals, and much altered. The quartz contains abundant liquid inclusions. Some of the crystals are much corroded, the magma having almost penetrated to the crystal centres from every direction.

The base is rarely felsophyric with abundant magnetite in grains.

Dolerites and Basalts.—Throughout the acid rocks just mentioned basic dykes occur in great numbers, so as to appear at times in the cliff faces as regular networks of veins.

The rocks are both holocrystalline and hypocrystalline, and consist principally of plagioclase laths and augite grains. Olivine is frequently present. Hornblende also occurs in certain types, but much decomposed. The olivine is principally decomposed.

Ophitic structure is noticeable in certain sections.

These basic intrusions belong probably to the Tertiary period.

Mr. Jukes and Professor Agassiz spent some considerable time on the Great Barrier Reef. Saville Kent also studied Barrier Reef problems on the spot for a period of twelve months. Jukes furnishes a section (reproduced by Agassiz, *l.c.*, p. 137) across the Barrier Reef and to the mainland which sums up his ideas of its origin, viz., that (even allowing for his exaggerated vertical scale), generally speaking, the continental shelf from the coastal plains of the mainland to the outer Barrier is composed of reef and reef débris. Notwithstanding this, his description is at variance with his section (*postea*, pp. 170-172). Jukes also says* that the Great Barrier Reef, longitudinally considered, " would be found to have a considerable resemblance to a gigantic and irregular fortification, a steep glacis crowned with a broken parapet wall, and carried from one rising ground [Sir C. Hardy's Islands] to another" [Breaksea Spit].

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* Jukes, Voyage of H.M.S. "Fly," Vol. i., p. 332-333.

Saville Kent* also concurs in Jukes's conclusions as to the origin of the continental shelf and the Barrier Reef as supplied by his (Mr. Jukes's) section.

Prof. Agassiz, however, claims that the forces of subsidence are unnecessarily called in by these writers, and that the coast (formed of granites and allied rocks) was planed down by the forces of marine erosion, and that coral and other reef-building organisms seized upon "the terraces of erosion" to which the coastal area had been reduced, and in this way by the coalescence of once isolated masses of coral, the Great Barrier Reef was determined in position.

The following extracts† illustrate the opinions held by Professor Agassiz and Mr. Jukes as to the origin of the Reef:—

"While it is undoubtedly true, as mentioned by Kent, that Jukes considered Darwin's hypothesis as 'perfectly satisfactory to my [his] mind,' yet I cannot help analysing Jukes's summary to show how correctly he had analysed the main features of the Great Barrier Reef, and of its relations to the mainland and intervening islands, and was led to what seem to me erroneous conclusions, from the inferences he drew from the diagram he gives of an imaginary section of the Great Barrier Reef, and which I here reproduce.‡

"It seems strange that Jukes should have given a section across the Great Barrier Reef, and have left out the islands which crop up nearly all along the coast of Queensland between the mainland and the outer or inner line of reefs. This would have given his section an entirely different aspect, as he would have had, cropping up and connected with the line of the mainland, a series of peaks rising from ten to thirty fathoms, round which alone, or round the flat bases of islands and peaks which had disappeared from erosion or other atmospheric causes, corals had grown Such a section is not an imaginary one, for the channels between

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* Saville Kent, The Great Barrier Reef of Australia; London, 1893.

† A. Agassiz, "Great Barrier Reef of Australia," pp. 136-139.

‡ Voyage of H.M.S. "Fly," Vol. i., p. 333.

the outcropping peaks, islands, reefs, or reef flats are covered with the telluric detritus derived from the decomposition of the rocks forming those islands, or obtained from the slopes of the mainland. Such a section would have shown the layer of corals to be comparatively thin, of not more than twelve to fifteen fathoms, and it would have shown the great probability that the outer line of reefs, even built upon similar bases, once connected with the mainland, had not attained a much greater thickness. See sections across the Great Barrier Reef (Plates xxxvii. to xli.). That Jukes himself felt his imaginary section and his explanation of it not to be of universal application can be proved from his own words.* He says :—

"'The most remarkable deviations from this condition are in the spaces between Cape Melville and Lizard Island, and at the back of Wreck Bay and Raine's Islet. Now in each of these cases there are islands of granite or other rocks advanced from the mainland, and thus causing an original irregularity in the depth of water, as it would be independent of the coral reef. This is very remarkable in the space between 12° 20′ and 11° 30′, where we have Cape Grenville, Cockburn Islands, and Sir C. Hardy's Islands, projecting towards Raine's Islet opening, and Fair Cape and Cape Weymouth, with Forbes Island and Quoin Island projecting towards Wreck Bay. Near Sir C. Hardy's Islands there is also a remarkable narrow channel of deep water, between them and the large Cockburn Reef, in which there is a depth of thirty fathoms, while on each side of it is either a reef nearly dry at low water, or a depth not exceeding ten fathoms. This channel is about twenty miles long, rarely more than two miles broad, and it runs in the same direction as the islands lie off Cape Grenville, or about east-north-east, and points in a straight line for Raine's Islet opening.'

"It seems to me that Jukes has here struck the correct explanation of the structure of the Great Barrier Reef. But having examined only the two extremes, he did not perhaps realise that the

* Jukes, Voyage of H.M.S. "Fly," Vol. i., p. 333.

same condition of things existed off any line in which such islands were found. He allowed his admiration for the simplicity of the explanation of the theory of coral reefs by Darwin to blind him to his own still simpler explanation, which I will here quote.*

"'In the first place, speaking generally, the outline of the Great Barrier Reef is parallel to the outline of the north-east coast. The one follows the other in all its curves and flexures with quite sufficient conformability to show that the two are connected. This is perceptible even in the small chart attached to this work, but still more remarkably so when the large Admiralty Charts are examined. It is evident that the circumstances that modified the outline of the coast likewise determined the general outline of the reefs. This is nothing else than to say, that the outline of the reefs depends upon the depth of the water. Just as in a large and accurate chart of any line of coast we should find the boundary of any certain line of soundings, such as 20, 50, or 100 fathoms, conforming generally to the outline of the coast, following its larger flexures and more important features; so we find the outline of the Barrier Reefs conforming to the north-east coast of Australia. Granting that the mean slope of the rocks, forming the original sea-bottom of this coast, was tolerably regular and conformable to the slope of the land, it is evident that if we took away the coral reefs and raised the land to any given height as, for instance, 100 fathoms, we should not greatly alter the outline of the coast, but only shift its situation. It would be thrown so much further forward, or towards the east. Now, suppose the coast cleared of coral reef, and raised so much that it emerged from the sea just within the line of the present Barrier Reef. Then let the reef commence in the shallow water along that shore, and a very slow and gradual depression take place, giving time for the polyps to build up so as to keep near the surface of the water. The result of this action would be the present Barrier with its steep outer slope, and its gradual extension over the sinking rocks that were once dry land within it. Portions that

* Voyage of the "Fly," Vol. i., p. 345.

were once hills on the dry land would now be islands between the Barrier and the main, such as Sir C. Hardy's Island and those about it. Islands that once existed in front of the mainland would now be altogether submerged, and their places only marked by detached reefs outside the Barrier, such as those north and south of Wreck Bay. According to the old rule of high land and deep water going together (in other words, the slope of the ground below water being only a continuation of that above), we should have the Barrier much closer to the present land in its more abrupt and lofty portions than in those which were lower and less highly inclined. We see accordingly the reefs approach the present land about Cape Melville, where the land is steep and lofty, and recede from it as we go further north in proportion as the land becomes flatter and more gentle in its inclination. Deep holes and ravines, full perhaps of fresh water, may have existed on the old land, so that when the surface of these lakes and hollows first sank to the surface of the sea, and admitted its waters, the bottom may have been too deep for the coral animals to live on. This would explain such a phenomenon as the deep narrow channel just north of Sir C. Hardy's Islands, with reefs running along each side of it. In short, every modification in the form and structure of the reefs is explicable by this hypothesis, and many difficulties solved, which admit of no other explanation.'

"He assumes, as we do, that the Australian coast at one time was just within the line of the present Barrier Reef; but it seems to me that the causes given by Jukes for the formation of the Barrier Reef are equally well explained by erosion and denudation. He assumes a great thickness for the corals on the outer edge of the Barrier Reef,—a thickness to have grown by the synchronism of the subsidence and the growth of the corals,—a thickness the extent of which no one can even guess at. We assume for the corals a thickness that can be determined fairly accurately as only a veneer of at most 20 fathoms upon the faces of the denuded platforms of the islands which once formed the outer line of the Australian continent. . . ."

Deductions from foregoing Observations with References to Geography of the Cordillera.

It is well known that coast lines of the regular or smooth type indicate (except in cases of riverless foreshores) a very advanced stage of marine erosion either in the present cycle or in one immediately preceding recent elevation, the tendency of marine erosion being to reduce irregularities, whereas the recession of the coast line from the edge of the continental shelf, combined with highly indented coast lines and numerous outlying islands, evidences the effect of recent subsidence.

The general trend of a coast line is due to earth movements, a very subsidiary part being played by the agencies of marine erosion, no inlets* or fiords arising as the result of such action, these being attributable to the subsidence of deeply eroded plateaux of accumulation or erosion.

Sedimentation also plays an important part in the genesis of coastal topography, the waste resulting from subaerial denudation being arranged to form deltas, coastal plains, shoals and spits. Marine erosion also helps in a lesser degree, but always in the way of forming a regular coast, viz., by attacking the headlands, the waste thus derived being formed into bars, or being swept into sheltered spots.

In forming any theory as to the origin of the present aspect of the Queensland and New South Wales coastal areas we may remember that :—

(1) The outer edge of the Great Barrier Reef appears to follow the general trend of the coast.

(2) The seaward edge of the Great Barrier Reef is not the only portion of the continental shelf-margin removed to a considerable distance from the coast line, since that part lying between Lady Elliot Isle (where temperature places a limit on the southward

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* Under "inlets" are not included those small irregularities in a coast such as exist between Port Jackson and Botany Bay Heads, but indentations like the above-mentioned ports themselves.

extension of the Reef) and the Tweed Heads is also of considerable width.

(3) The Barrier Reef rises suddenly from great depths, but in a less marked degree than does the shelf eastwards of Moreton Bay and Sydney Heads.*

(4) The great shoals of the shelf in the neighbourhood of Stradbroke, Moreton and Frazer Islands are arenaceous and argillaceous in character, and small calcareous patches, as Lady Elliot Isle, have grown on the northern extension of one of these banks.†

(5) Between the outer Barrier and the mainland the average depth of the water is from 10 to 20 fathoms. A few depths exceeeding 30 fathoms have, however, been recorded in the vicinity of Wreck Bay.‡

(6) The Great Barrier Reef itself is of variable width, and is broken up by long passages arranged parallel and transversely to its length. The depth of the water in these "lanes" or passages varies from about 20 to 40 fathoms.

(7) A maze of islands exists on the shelf, occupying a zone of from 10 to 15 miles from the coast, close together inshore and scattered in an easterly direction; 20 miles off shore no trace of continental island occurs above H.W.M. In size these insular areas vary from several acres to rugged mountainous masses, like Hinchinbrook Island 20 miles in length and 3,600 feet in height, or huge masses of sand dunes as Moreton, Stradbroke and Frazer Islands. Frazer Island is 80 miles in length, has a great spit continuing from its northern extremity, with a fairly meridional disposition, and the eastern coast forms a long uninterrupted curve. Moreton and Stradbroke Islands have lines of sand dunes as much as 800 feet in height, and show masses of continental rocks at their northern extremities. All of these three large sandy islands are associated with large sand shoals, island

* See also A. Agassiz, Bull. Mus. Comp. Zool. Harv. Coll. xxviii., pp. 129, 140, 141.

† Jukes, Voyage of H.M.S. "Fly," Vol. i., p. 318.

‡ Jukes, *Ibid.*, p. 333.

tying in various stages, and extensive coastal plains. They occur also in proximity to large rivers.

(8) On the mainland and islands of Queensland the occasional evidence of small cliffs is present, although typically conspicuous by their absence. (Cliffs are noticeable on the N.S. Wales coast, and are very pronounced on the Tasmanian seaboard.) Immense rugged escarpments exist on both mainland and insular areas. These abut in many cases on to wide coastal plains. Large beaches and coast plains exist also on the leeward sides of the islands sometimes as much as 20 feet above H.W.M., while examples of tied islands are frequent, as at the Palms, Hinchinbrook and Dunk Islands.

Fringing coral reefs are associated with most of the islands.

(9) Lagoons and lagoon-marsh meadows are of frequent occurrence along the coast, especially so between Townsville and Sydney Heads. At Ballina* (just south of the Queensland area) there exists a great extent of low land encircled by an amphitheatre of hills. Long lines of sand dunes on this area curve sympathetically with the coast line. Lagoons have been formed between successive dunes to be changed subsequently to lagoon-marsh meadows. A still later phase here is elevation and encroachment by the sea, as shown by the peaty products of the marshes being exposed in the present coast nips.

(10) Bay bars and spits have a great distribution.

(11) South of the Great Barrier Reef numerous rivers, of which the Brisbane, Tweed, Richmond, Clarence and Macleay may be taken as types, pursue general easterly directions to within a few miles of the coast, when they flow to sea along northerly channels sometimes as much as 50 miles in length.

The country east of these deviations is typically of flat, low, sandy or swampy nature. River bars exist at the entrances. Although the rivers have a general easterly flow, the head waters frequently follow meridionally disposed channels.

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* J. E. Carne, Ann. Report Dept. Mines N.S. Wales, 1896, p. 151.

(12) Along the present seaboard the coastal plains maintain a fairly constant height above sea level. A few miles inland from Townsville, however, along the flanks of the ranges, recent deposits occur at elevations* of as much as 300 feet above sea level. Variable heights at which Post-Tertiary deposits occur may be seen at the Hunter River mouth and Raymond Terrace (E. C. Andrews), Maitland district† (50 feet; David and Etheridge).

(13) Splendid examples of consequent drainage occur on the coastal plains of Hinchinbrook Island, Townsville flats, Palm, Dunk Island and other places.

(14) The coast is attended by a wide upland, rising gradually towards the west until an elevation of about 4,000 feet is attained. Considered broadly, this mountainous belt is represented at the coast merely by undulating country, rising occasionally into isolated mountains. Still further west the monadnocks crowd together until the country has the aspect of a maze of wild ravines from 2,000 to 4,000 feet in depth, separated by long razor-backs, the summits of which would lie on the surface of a flattened hemi-cylinder, the decrease in height taking place in an easterly direction. The central and highest portion of the mountain mass consists of undulating tableland. Flat basaltic hills occupy the highest points, and overlie numerous extensive and deep masses of auriferous river drift. These old water courses far exceed in size those of the present streams. The central portion of the cordillera consists principally of various granitic rocks, while to east and west lie the variously inclined rocks belonging to the Palæozoic era. On the upturned edges of these the old rivers ran. A most interesting feature in the present topography is the generally wide and shallow series of basins (with basaltic outliers), in which the present streams run, and the numerous long and narrow cañons, 2,000′ to 4,000′ in depth, which are entrenched along the recent broad basins of the present streams.

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* Jack and Etheridge, Geology of Queensland, p. 617.

† David and Etheridge, Rec. Geol. Survey N.S. Wales, 1890, ii., Pt. 2, pp. 37-52, pl. 3.

In a mere advance-note like the present the proper discussion of the above observations would occupy too much space, but briefly their philosophy appears to me to be much as follows :—

The coincidence of Barrier Reef and present coastal contours points to an occupation by coral growths of a former coast line, but the continuance in width of the shelf southwards of the limits of reefs (coralline), and the great shoals thereon, points to a minor part only of the shelf being formed of coral growths.

It would appear that the almost uniform and smooth bottom of the outer centre and eastern portions of the continental plateau, combined with the great depths from which the Barrier rises, argues a long period of marine erosion preceding the present cycle* during which a uniform coast and smooth off-shore bottom had been formed. The sinking of this uniform area allowed the sea to trespass far over the old coast sands into the ranges, and the corals — formerly prevented from forming barrier reefs, by reason of the practical coincidence of continental shelf margin and shore line, and the excessively turbid character of the water on the narrow fringe of the continental shelf—proceeded in the clear waters of the shelf margin, now removed far seaward, to invest the whole width of the smooth off-shore deposits with their masses, and establish themselves as the Barrier Reef.

Some connection probably exists between the present Reef passages (and parallel channels) and the old watercourses of the coastal area.

The association of numerous rugged mountainous islands on the inner centre of the shelf (and close in shore) and smooth shallow interinsular seabottom, combined with traces only of coastal nips, is suggestive of gradual subsidence with concomitant sedimentation rather than a period of equilibrium succeeding subsidence which would result in the formation of cliffs.† Magnificent

* Cycle—the time involved in a movement of considerable extent or in the development of a submarine plain or peneplain.

† The existence of bar-bound rivers has, however, to be taken into consideration.

examples of drowned topography occur in the neighbourhood of Hinchinbrook Island, also in N.S. Wales in the vicinity of Port Jackson and Hawkesbury River. To the south of Queensland longer continued marine erosion during periods of more stable equilibrium is shown by the cliffs of Sydney district, Victoria and Tasmania. (This after pronounced movement or movements of depression.)

The existence of islands like Frazer, Moreton and Stradbroke, and widespread extensive coastal plains of the Queensland area, the tombolos* of the shelf islands, the lagoons and lagoon-marsh meadows, the bay bars, etc , all point to the adolescent and late adolescent stage of development attained by the Queensland coast. These features are necessarily more accentuated south of the Barrier owing to the increased wave-action in Extra-Barrier areas. When the harbours of the coast become silted up, the headlands cut back. and the sea able to carry out its intention of establishing a straight or gently swinging shore line, then will the coast have advanced to maturity. That period is far away at present, although even this stage has been attained in certain small areas, seeing that elevation has accelerated the movement. The straight eastern shore-line of Frazer Island is suggestive of maturity for that particular spot. Here, however, the sea has had a sand mass only to work on.

The situation of Frazer Island, the distribution of the great coastal flats, the deflection northwards of such streams as the Brisbane, Tweed, Clarence, Richmond and Macleay, points to a dominant along-shore current from the south, and a weak fluviatile action. The streams, in their attempts to push their loads off shore, are opposed by a stronger wave action which piles up river bars; a dominant current redistributes the débris along its own path, offsets and overlaps occur, and finally the stream is deflected for miles out of its normal course.

The occurrence and present aspect of the coastal plains and allied features at heights above sea level argues a general elevation in historic times for the coast line itself.

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* A sand bar connecting two islands, or islands with mainland. Gulliver "Shoreline Topography." Proc. Am. Acad. Arts & Sci., 1899, xxxiv.

The appearance of the coastal area is explained by the forces of subaerial denudation acting on a plateau till a period of maturity and old age, when the general outline of the upland would have vanished, with only a few mountains left amidst the undulating country to show its former extent. The extreme old age of this area will be reached when it is reduced to a peneplain. It must be remembered that mature dissection of an upland is not necessarily associated with a mature neighbouring coast, since the ranges may have been developed to this stage in a cycle preceding a crustal movement which would place the coast line in its initial stages when the other was already mature.

The frequent occurrence of wide and very thick masses of river gravel underlying the various Tertiary basaltic flows of the tableland, and now associated with the present insignificant streams only, points to a cycle of erosion antedating the present one. In this first cycle several basaltic outbursts occurred, and the present 3,000 feet level of the New England plateau was developed near sea-level, since which period a 3,000 feet elevation has taken place and the present coastal forms evolved. The upland elevation and coastal subsidence* indicate a differential movement from east to west, while the various phases of shore development show a variable movement from north to south. The subsidence was accentuated seawards, therefore the Barrier Reef is probably of some considerable thickness, though forming but a mere fraction of the mass of the continental shelf.

One of the most instructive and interesting features in connection with this subject is the still more recent differential movement from east to west. On the most easterly limit of the Great Barrier no records exist of any trace of elevatory movement; closer in shore Mr. Jukes and Professor Agassiz found abundant signs of a slight movement varying from 5 to 20 feet above H.W.M. Large terraces and coastal plains exist on the mainland, up to as much as 300 feet in one instance.

On the eastern uplands themselves the recent streams which have flowed over the plateau in broad and shallow basins now

* The coastal subsidence, however, postdated by a long period of time the last considerable elevation of the plateau.

precipitate themselves over precipices in places 1,000 feet in height.

Lower down* the cañons attain a depth of 3,000 feet, and are entrenched upon their former basins, while the general level of the plateau persists for as much as 30 miles beyond, only broken up by these inaccessible falls, often but a few hundred yards in width, and not noticeable a quarter of a mile away. The traveller may wish to reach a hill four or five miles distant across the gently undulating plateau, but a detour of many miles† must be made in order to cover the short intervening space, the gullies trenching the upland being practically impassable. This points to a late rejuvenescence of the plateau—the hydrographic system was disturbed, and "valley in valley" structures induced, terminating in gigantic waterfalls. Withal, however, there appears to have been no deflection of the streams by the formation of the anticline, since the cañons open along the recent stream basins into the old valley and plain tracks. This then points to stream revival.

The general east and west trend of the coastal streams shows consequent drainage attendant on the seaward slope of the upland during previous elevations, while the long north and south courses of the head waters of such rivers as the Fitzroy, Brisbane, Clarence, Hawkesbury and Shoalhaven tell a tale of subsequent drainage determined by the dominant meridional strike of Palæozoic rocks varying in hardness. These "strike" streams point to a youthful stage in stream development. Such rivers as the Hastings, now completely encircled by the "strike" streams of the Manning and Macleay, may in time capture the latter, owing to their steeper grade allowing them to eat back more quickly into the plateau (unless checked by very resistant structures the while the individual streams cut their way down approximately to base level). This will mark the graded stage

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* 5 to 15 miles.

† Special reference is here made to the cañons of the Upper Macleay waters (New England).

for the upper courses of our coastal streams, since waterfalls and rapids will then be no more.

Instances of these interesting phases of river development might be multiplied from the cordillera.

It appears, then, that probably at some period in Tertiary time, immediately preceding the present cycle, the Queensland coast (as also that of N.S. Wales) ran parallel to, although at a considerable distance from, the present shoreline, and that shore development had advanced to the advanced old age stage as a result of long-continued marine erosion and sedimentation. An old upland* curved sympathetically with the coast, and was coeval with it. The evidence goes to show that immediately prior to the great movement obtaining at present, this old land was dissected by subaerial agencies as to its eastern and western portions to a stage of old age. A differential movement was set up, involving such forms of stress as tilting, folding, faulting and warping, the motion varying both from east to west, and from north to south. The pivotal axis was probably an inconstant quantity, although confined in the main to the neighbourhood of the centre of the cordillera. It may be stated here, although the discussion is reserved for a future paper, that at the close of the Cretaceous period a long protracted cycle of erosion resulted in the formation of a plain almost at sea-level in the area occupied now by the tableland. An elevation of 1,000-1,500 feet took place in the early Tertiary period ; while the new cycle of development was in a fairly advanced stage, several distinct basaltic outbursts occurred, each separated by long intervals of time. The plateau was then worn down to the old age stage, when another cycle of elevation intervened, forcing the Cretaceous and Tertiary peneplains an additional 3,000 feet above sea-level. Reduction of the plateau was then started afresh by the swiftly falling streams, and after an anastomosing series of cañons had been imposed upon the plateau, accompanied by mature or old age coastal development, a minor cycle of subsidence ensued for the coastal area, of

* Plateau of erosion.

Pleistocene age. This subsidence determined the present Barrier Reef. What the immediately antecedent stage to the early Tertiary uplift of the Cretaceous peneplain may have been is not known at present. Secular movement is, however, doubtless the key to the initial stages, while subsidence with concomitant sedimentation was merely an after factor in the evolution of the main features of the present shore line topography. The presence of small cliffs only on the markedly irregular Queensland coast, combined with the even seabottom of interinsular areas, and the great extent of coastal plains, argues a gentle subsidence combined with filling of sunken coast valleys, while marked depression succeeded by more stable conditions during which marine erosion could cut cliffs is hinted at by a study of N.S. Wales, Victoria, and Tasmanian coasts. Shore-grade* was attained in places, and island-tying was effected by the complicated processes of along shore action. Splendid examples of this action are illustrated at Challenger Bay in the Palms (marine erosion), at Hinchinbrook Island (complication of tide, along shore current, marine erosion, fluviatile action, and elevation), Stradbroke, Moreton, Frazer, Curtis and other islands. Gain to the coast was accomplished by the development of coastal plains. Bay bars were produced by wave and current action, while similar processes resulted in the formation of lagoons, lagoon-marsh meadows, and successive aggradation lines curving sympathetically with the shore line,† while bays were becoming silted up by fluviatile and æolian agencies after the formation of bay bars.‡ During this period

* An adolescent feature—attained when transportation occurs along shore, with island tying and formation of bay bars.

† Line of intersection of the sea with the land. Gulliver, "Shoreline Topography."

‡ Port Jackson is an example of a ria or submerged subaerially curved valley, which owes its commercial importance to its steep off-shores, the absence of large streams discharging either into it or into the sea immediately south of the Heads, thus preventing silting up by river action, or the redistribution of river loads by wave and dominant along shore current (south) action to form spits and bay bars.

Botany Bay is an instructive lesson in the filling up of a submerged valley by river and æolian action aided by recent elevation. Aggradation lines are seen on the large flat near Lady Robinson's Beach.

the dissection of the eastern uplands was carried on from the maturity of the previous cycle to a very slightly advanced stage during the cycle of subsidence. The subsidence of the coast gave diminished stream action along the lower portions of the watercourses. River grade was also reached, no falls interrupting the courses of the streams.

The sinking of the maturely (or adolescently) developed coast and shore of the previous cycle was the occasion of its investiture by coral growths to form the Great Barrier Reef. These growths kept pace with the gradual subsidence, and, as in other coral reef regions, numerous deep water lanes became coexistent with the growth of the Great Barrier, being determined probably in part by the old watercourses of this area of drowned topography. The evidence points to the limitation of luxuriantly growing coral masses to the outer centre and edge of the shelf, owing to the turbid water west of the centre of the shelf, the recession of the shore line from the edge of the continental plateau permitting of their existence in the clear water to seaward, while the turbid water of the closer inshore area militates against its western expansion. Exceptions occur in the deeper off-shore areas of mountainous coasts possessing inconsiderable streams (coast north of Cairns). The inner and central portions of the fairly flat continental shelf seem determined by the conjoint influences of tides and dominant currents in the way of redistributing the loads brought down by the rivers, and the material lost to the islands and mainland by the agencies of marine erosion. Gain to this area is also represented by various animal and plant growths containing calcareous tissues, coral growths being confined to the formation of island fringing reefs.

This cycle of coastal depression was interrupted in modern times, as regards the shore,* by an epicycle of elevation, which may have originated in a shifting of the pivotal axis, inasmuch as that, while apparent elevations along the coast line are con

* The anticline to the west across which the cañons of the coastal rivers have sawn their way appears to have been in process of formation for a considerable period.

fined between vertical limits of 5 and 20 feet, traces of contemporaneous elevation exist inland from Townsville to the extent of 300 feet; terraces also occur at Raymond Terrace about 20 feet above sea level, while some 10 miles to the west traces of the upward movement occur as much as 50 feet above present high water mark. From observations made in North Queensland and along the New England plateau the topographical features of the central and eastern portions of the cordillera record a double cycle of elevation. The hydrographic system was disturbed; the broad shallow basins which had been developed in the plateau after the Tertiary basalt outbursts were forced upwards again in much more recent times, the criteria of later elevation consisting in the "valley in valley" form of the river systems. The cañons of such rivers as the Macleay, 2,000 to 4,000 feet deep, occupy the centres of their former basins, and end in gigantic waterfalls sometimes 1,000 feet in height. Other examples of recently disturbed drainage systems are :—

(1) The Barron, Tully, and Johnson falls in N. Queensland.

(2) The various Clarence and Macleay falls in New England.

(3) The Nepean and Shoalhaven falls in southern N.S. Wales.

A youthful stage in stream development is also hinted at by the "strike" streams of the upper waters of the coastal rivers. More steeply graded rivers travelling westwards from the coast may hereafter catch the long meridionally disposed headwaters of streams like the Clarence, Shoalhaven and Nepean.

The recent epicycle of elevatory coastal movement accentuates such features as island tying, the formation of lagoons, coastal plains, bay bars and silting up of bar-bound harbours.

Such rivers as the Brisbane, Richmond, Clarence and Macleay furnish magnificent examples of the dominance of a southern along-shore current, and the evident intention of the sea to establish a straight shore line in the enormous deflection northwards of these streams and the presence of huge bars at their mouths. Other evidence of the influence of sea action is manifest from the position of Frazer Island, the uninterrupted sweep of its eastern coast, its extensive northerly spit, and the gently swinging coast south of the island backed up by lagoons and lagoon-marsh meadows.

Criteria of the adolescent stage in coast formation appear to be frequent, while maturity is still far away in point of time, as is shown by the presence of numerous irregularly shaped islands and headlands with attendant unfilled lagoons, bays and harbours.

From a consideration of the plateau and coast features, there appears to be no reason for assigning an age later than Pliocene, possibly late Pliocene, for the movement of elevation which carried the Tertiary and Cretaceous peneplains 3,000 feet above their former positions and resulted in the formation of the cañons and upper valleys of the coastal area. The subsidence which determined the present Barrier Reef may be referred to Pleistocene times on topographical grounds, while the latest epicycle or vibration of coastal elevation may be referred to the historical period.